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COST OF PRODUCING PULPWOOD ON FARM WOODLANDS OF THE UPPER CONNECTICUT RIVER VALLEY

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[1] Maintained at New Haven, Connecticut in cooperation with Yale University.

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APPENDIX

COST OF PRODUCING PULPWOOD ON FARM WOODLANDS OF THE UPPER CONNECTICUT RIVER VALLEY

The Farm Woodlands of the Upper Connecticut River Valley

More than half of the average farm in the Upper Connecticut River Valley supports some type of forest growth. These forested areas, properly described as farm woodlands rather than woodlots, fall into three general classes:--first and most important, even-aged spruce and fir stands originating on old fields, pasture, or following logging and pulpwood operations; second, sugar bushes; and third, typical northern hardwood stands. These farm woodlands furnish owners such rural necessities as fuelwood, fence posts and lumber, but even more important, they supply pulpwood which brings the average Upper Connecticut River Valley farmer $300 in cash, an amount exceeded only by returns from his dairy products. A recent survey of forest resources in this region indicated that with good forestry practice farmers might readily produce more than 60,000 cords of spruce and fir annually.

Ordinarily, pulpwood finds a ready market at prices that leave the owner a good margin for stumpage. Furthermore, in addition to stumpage, an owner may increase his cash income by doing the work of cutting and hauling either alone or with a helper. Pulpwood operations can readily be coordinated with the regular farm program, as the work, except for peeling, can usually be extended over about eight months to suit the owner's convenience. A further point is that pulpwood jobs, aside from trucking, seldom require special tools or equipment not commonly used on a farm. Owner-operators provide the best assurance of a good land management policy as the future development of the tract receives the owner's careful consideration, while a contractor or an operator buying stumpage has no interest beyond immediate returns.

Farm woodlands of the Upper Connecticut River Valley play an important part in supplementing material shipped from Canada and the less accessible wild lands of New Hampshire, Vermont, and Maine, which supply the mills in this region with most of the pulpwood. Using local wood is usually advantageous to both buyer and seller. Farmer's wood, purchased C. O. D. at the plant, relieves the mill operator of the investment and responsibility incidental to cutting and hauling, while small woodland owners benefit under this arrangement through assurance of a local market for their pulpwood. Loss of market for such an important cash crop would financially hurt many of the farmers, and this in turn would be reflected in the prosperity of the local communities.

The Forest Products Cooperative Association

Farmers producing small quantities of pulpwood cannot as individuals bargain effectively with prospective purchasers. Buyers for the pulp mills may not intentionally discriminate against small producers, but increased supervision and bookkeeping costs necessarily mean lower prices than could be paid responsible parties handling large volumes of wood. Middlemen ordinarily bridge the gap between producer and consumer, buying from the farmer and small contractor, and, having assumed responsibility for all details incidental to delivery at the mill, receive a price that includes a reasonable commission.

In order to overcome the handicap of being small producers, about 300 farmers in northern Vermont and New Hampshire organized the Forest Products Cooperative Association in 1935, with headquarters at Groveton, New Hampshire. In planning for this Cooperative, pulpwood naturally received primary consideration as compared with forest products less important locally, such as logs, Christmas trees, and maple sugar. This Cooperative organization performs various essential functions. It finds markets and contracts for delivery of forest products, in this respect displacing the commission man. It provides members with financial assistance necessary to carry on woods operations. It also arranges for an educational program, to stimulate better forest management practices and to maintain farmer participation.

The role of the Association as banker undoubtedly sold the Cooperative to a considerable number of members. To have a broker acting in the interests of the producer appeared to be good economy, particularly as the margin formerly paid the commission man must largely carry the Association overhead. However, in order to fully justify and insure its continued existence, the Association must provide its members with worthwhile services not formerly available. This can be best attained by an educational program having as the ultimate goal a land management program involving the maximum sustained production of valuable timber crops on the holdings of all members. Surveys, inventories, and experimental work, together with market and other special studies, provide the basis for such a sound program of education. The educational program is carried on by the State Extension Service and the United States Forest Service, and includes individual advice to landowners in the form of woodland management plans, meetings, discussions, and practical demonstrations. The work has the support of the Forest Products Association, Inc., and is carried out in accordance with a cooperative agreement between the New Hampshire State Extension Service and the Association. Although primarily concerned with the farmer, this program should develop in the consumer as well as the producer, a better understanding of problems of mutual interest.

Production Cost Study

Primarily to determine the practicability of making partial cuttings in second growth stands of spruce and fir, a study of costs of producing pulpwood was undertaken by the Northeastern Forest Experiment Station in connection with operations of the Forest Products Association. This study, indicating the possibility of developing silviculturally desirable methods of cutting, provides the type of information essential for the educational program sponsored by the Forest Products Association. As a basis for recommending any changes in customary local practice, the cost of producing pulpwood study necessarily involved a detailed analysis of all phases of representative operations from the time the trees were cut until delivery of pulpwood at the mill. Although a means to an end from the land management standpoint, the time and cost phases of this study have further utility in providing the pulpwood operators and landowners with data applicable to going operations. Available in this report, these data indicate effect of size and species on costs of production, provide a basis for allocating costs to different phases of a job, and bring out the efficiency of different operating methods and crew organization.

Scope

Undertaken as an emergency relief project, the study covered only smaller peeled pulpwood jobs in second growth spruce and fir stands. In order to work efficiently with the same observers, largely local unemployed, the project was restricted to operations in the immediate vicinity of Colebrook in Coos County, New Hampshire. Farm pulpwood operations in this locality appeared typical of the region, yet, provided normal variation in stands, logging conditions and methods, and crew organization. In obtaining an adequate sample of all phases of producing pulpwood, the study covered 19 different pulpwood operations employing 57 different workmen. About 5,000 merchantable spruce and fir trees were included. The number of operations and men involved would have been reduced had it been feasible to follow each operation through a complete cycle from stump to mill.

When initiated, high priority was assigned to determining costs of producing pulpwood as affected by method of cutting. A dearth of light partial cutting jobs precluded the possibility of obtaining any considerable number of direct observations on operations other than those conforming to usual clear-cutting practice. Admittedly much less satisfactory, comparative costs for different methods of cutting as indicated in this report are in some cases based on the size distribution making up the cut, ignoring methods of cutting as such.

The time study naturally fell into six distinct phases, as follows:

Felling, limbing, and peeling. With these operations were included swamping around the base of the tree preparatory to felling, cutting branches from standing trees, and trimming of knots after peeling. Both axe and spud work were included in peeling.

Bucking involved cutting the peeled sticks into four-foot bolts either in the woods or, if skidded in tree lengths, at the landing.

Piling consisted of stacking four-foot wood in readily measured piles, accessible for hauling by scoots, sleds, or trucks.

Skidding in tree lengths to truck landings for maximum distances of 600 feet was the practice on the majority of the operations included in this study.

Yarding of four-foot wood prevailed on less accessible areas where it was impractical to bring a truck within reasonable skidding distance.

Trucking from landing to mill is the logical procedure in the Colebrook region as distances were too great for teams and not great enough to justify railway transportation.

Methods

Observers obtained stop watch time records on all phases of the study which, together with pulpwood volume and tree measurement data, provided an accurate and detailed indication of output and production costs. To forestall a possible distortion of normal results, observers were instructed to obtain the data without interfering in any way with the usual conduct of the workmen.

Each of the six phases of the study was treated separately in the analysis, no attempt being made to segregate data for the same trees appearing in more than one phase of the study. Likewise, men doing different types of work were treated as separate and distinct working units.

Records included the time for each productive phase of the operations, and also accounted for all non-productive time. As an office computation, all legitimate non-productive time was charged to individual trees, the procedure for normal travel time between trees in the felling operation, or totalled for the entire job and prorated on the basis of the recorded productive time per tree. As non-productive time was an important consideration on most operations, failure to properly distribute this item might well distort results and conclusions.

In obtaining a cross-section of pulpwood operations in the region, tables and figures are based, wherever possible, on the output of several units covering a variety of working conditions.

Results

Felling, limbing, and peeling.--Study of felling, limbing, and peeling included data on 875 trees 4 to 13 inches in diameter, distributed over 11 representative operations. More than 60 percent of these trees were balsam fir, about 35 percent were red spruce, and the remainder, white spruce. Size of working unit varied; six were of two men, four choppers worked alone, and on the eleventh job three men made up a crew. More than half of the basic data applied to two-man crews, about one-third to men working alone, and less than 100 sample trees to the three-man unit. Comparative costs in making commercial clear-cuttings and silvicultural selection cuttings were obtained on one job.

Tree size was the most important factor affecting costs per cord. Small trees involved a disproportionately large expenditure of time, particularly in felling and peeling. As illustrated by figure 1, a 2-man crew felling, limbing, and peeling a cord of pulpwood obtained from 4-inch spruce and fir trees would require approximately 16 and 12 man hours respectively, while the same volume could be obtained from 13-inch spruce in about 6 hours and from fir trees in about 4 hours. The same general size relationship, that exists between size and volume output for a 2-man crew, applies also to 1- and 3-man working units, indicated by figure 2. In general, time per cord required for each phase of this operation decreased with an increase in diameter. An exception was limbing time for spruce trees above the 10-inch diameter class, where a slight upward trend was shown. Labor involved in limbing these larger spruce was excessive because many trees were heavy limbed, open grown "bull spruce". Cost of limbing was the major factor in all except the 4-inch diameter class, and constituted more than half of the total cost for the larger sizes.

Figure 2 indicates that one man working alone proved considerably more efficient than a 2-man crew, while 3-men were the least efficient unit. The latter assumption, although undoubtedly true for both species, is based largely on fir because very few spruce trees were cut by the 3-man crew. With an increase in diameter, spread between output for 1- and 2-man crews, and for 2- and 3-man crews remained fairly constant. About 30 percent more time was consumed by a 2-man as compared with a 1-man crew, and about 12 percent more time for 3- than 2-men. The spread became less pronounced in the larger diameter classes, and had data been available, the effect of crew size would probably have become relatively unimportant for trees above 13 inches in diameter. From the non-productive time standpoint, an important factor in the felling, limbing, and peeling operations, one man working alone showed up to excellent advantage. Several factors favored the individual chopper. He had no partner to wait for or visit with. No one stood idle while he undercut or

wedged the tree. Furthermore, less time was spent moving from tree to tree because one man works over a smaller area than two men. With an increase in tree size, the 1-man crew failed to maintain quite the same advantage for three reasons: first, non-productive time was relatively less important; second, two men form a very efficient unit in felling large trees; and third, aside from felling, the men work singly a considerable portion of the time in any event.

Other factors being equal, costs were materially lower in producing a cord of balsam fir than a cord of heavier and harder spruce pulpwood. Reference to figure 1 indicates that species, particularly in the upper diameter classes, has very little effect on time required for felling. However, the figure shows that fir, particularly in the smaller diameter classes, peeled more readily than spruce, and that the most significant difference in output occurs in limbing, where spruce required considerably more time than fir, especially in the larger size classes. The felling, limbing, and peeling aspect of the study necessarily included rather complete measurements of each stem and thus provided much data on form and volume of second growth spruce and fir. Such data from 597 trees form the basis for table 1.

Bucking.--Most of the bucking data covered 1- or 2-man crews, with a limited number of observations on a 4-man unit using a power saw. As a further breakdown in analyzing time involved, trees were segregated on the basis of species, either spruce or fir.

Bucking small trees proved relatively costly. Approximately twice as much time per cord is required to buck 4-inch as compared to 13-inch trees. Figure 3 indicates that bucking costs did not decrease uniformly with increased diameters, but dropped abruptly in the smaller sizes, 4 to 6 inches, and relatively little in the upper diameter classes, 10 to 13 inches.

In working up smaller trees a very high proportion of the time was consumed in measuring for saw cuts, and moving the trees or getting into the proper sawing position. With an increase in tree size these non-productive but chargeable items per stick remained approximately constant, increasing slowly beyond the point where trees could be readily handled.

As a basis for rating efficiency of various crew organizations and determining output in the woods and at the landing, this study in timing eight 1-man and six 2-man crews included a representative cross-section. It is evident from figure 3 that one man cutting alone constituted the most efficient working unit, and that he could buck up about 25 percent more volume on the landing than in the woods. Working alone in the woods, he was somewhat more effective than a 2-man crew on the landing, while two men in the woods had the lowest output.

Data on fir, shown in figure 3, appear to contradict the above ranking, as two men on the landing seem the least efficient unit for size classes less than 6 inches, and in classes above 8 inches are surpassed only by one man working alone. One of the slower 2-man crews worked up a considerable proportion of the small fir, while two of the more efficient 2-man crews bucked up most of the fir above 8 inches. Although the figure correctly portrays the basic data, it seems probable that two men cutting fir on the landing would normally occupy the same relative position indicated for spruce. That is, for all size classes a slightly lower output would be shown for one man working in the woods. Properly placed skids and saw horses increased efficiency at the landing, while in the woods output per man hour was lower because of less favorable working conditions and time lost in moving from tree to tree.

Bucking at the landing with a power saw on a single job provided only an indication of the relative merits of this method as compared with handwork. This home-made unit, equipped with circular saw, a stationary saw table, and powered with a Ford model T engine, is typical of saws used locally for cutting cordwood. A 4-man crew, working with the power saw at the landing, proved slightly less efficient than one man working alone on trees below 9 inches in diamater. Above the 8-inch optimum, time per cord increased to more than 150-man minutes per cord for 13-inch trees. A reorganization of the work would undoubtedly have increased efficiency because, in handling larger size classes, 2 or occasionally 3 members of the crew did nothing productive while trees were rolled into sawing position. Based on general observations a power saw handled by three men would probably prove more economical than a 4-man unit. Saw table height, well above the landing skids, reduced efficiency, particularly in handling large trees. This adverse factor would be eliminated in a well planned layout in order to work with, rather than against, gravity. Time lost due to mechanical difficulties, investment, upkeep, and gasoline costs are factors not considered on this operation that would necessarily be taken into account in determining the practicability of power bucking. Use of power saws on a landing certainly warrants further study, particularly on jobs where small trees predominate.

In order to obtain a more precise comparison between species, the work of a single efficient 2-man crew working at a landing is shown in figure 4. This figure is based on 283 spruce and fir trees, with a good scatter in diameters from 4 to 13 inches. For trees of a given size, less time was consumed in bucking a cord of fir than a cord of spruce. The spread of approximately 10 percent for the lower diameter classes decreased to about 2 percent for the larger sizes.

Piling.--Basic data collected on this relatively unimportant phase of the study were frequently inconsistent and generally unsatisfactory. Variations were largely due to failure of the men to maintain a steady pace, particularly when piling in the woods. This task is sometimes hurried through at the end of the day, and

sometimes leisurely accomplished as a rest after bucking. This erratic work in some cases offset, in others exaggerated, the logical effect of such important factors as size and number of sticks per cord, and carrying distance to piles. Average figures based on work of seven different crews indicated that piling required 43-man minutes per cord of wood when made up of 119 sticks and carried an average distance of 14 feet. Pulpwood was frequently piled between two trees or at least against one tree, but in the absence of standing trees, racks were built, an item accounting for an average of ten minutes per pile.

In addition to detailed piling information volume data were obtained to determine solid wood content and number of sticks of different sizes contained in a stacked cord of 128 cubic feet. These data are presented in table 2, column 3 of which is based on values read from a curve. This curve was extended beyond limits covered by field measurements to include piles having average stick diameters of 4, 11, 12, and 13 inches. The last column of table 2 indicates theoretical number of sticks per cord calculated on the basis of a weighted average figure of 95.8 cubic feet per cord, ordinarily a satisfactory conversion factor for peeled second growth spruce and fir pulpwood. Solid wood volumes increase with stick size, a cord containing 93.4 and 99.6 cubic feet when sticks averaged 4 inches and 13 inches respectively. Actually, extremes are unimportant since more than 90 percent of the typical samples included in this study had average stick diameters between 5 and 8 inches, involving deviation of not more than 1.3 cubic feet from the 95.8 cubic foot average.

Skidding.--Skidding data obtained on four different jobs covered 192 trips over distances (one way) of from 89 to 600 feet. Although some variation occurred, all skidding chances were classified as good. The ground was never soft or wet enough to materially affect travel time. Topography was either level or sloping moderately from woods to landing. The driver generally loaded in the woods and unloaded at the landing without assistance. Depending largely on tree size, loads of from 1 to 7 spruce and fir stems had total volumes ranging from 1.8 to 25 cubic feet. Travel accounted for slightly more than half the time in making an average trip; of the remainder, loading in the woods required 50 percent more time than unloading at the landing.

The following regression equation was developed in order to properly weigh the several factors and present results in readily usable form:

$$S = \frac{.029\,D + 6.8\,C + .89\,N - .65}{C}$$

in which S = Skidding time per cord in minutes
D = Distance in feet
C = Load in cords
N = Number of trees in load

Size of load is a more important factor affecting time per cord than travel distance, while number of trees making up a load has the least significance. The formula has a standard error of ± 3.8 minutes, and is applicable to other jobs of the same general type. However, good judgment is essential to proper use of this equation. Theoretically, costs per cord steadily decline with an increase in volume, but in practice, skidding with one horse has very definite limitations. An operator interested in calculating probable skidding costs would necessarily estimate number of trees and volume that would make up representative loads; also determine average skidding distance. On a reasonably uniform chance one solution would suffice. However, stand or topographic differences might necessitate several calculations properly weighted.

Practical application of the equation can be best illustrated in solving a hypothetical case. Assume an operator estimates 4 trees containing .15 cords (14.4 cu.ft.), make up a representative load to be skidded an average distance of 400 feet. Solving the equation using these values:

$$\text{Skidding time per cord} = \frac{.029\ (400) + 6.8\ (.15) + .89\ (4) - .65}{.15} = 103.5$$

Having determined the time required (103.5 minutes) for a driver with one horse to skid a cord of wood, it is only necessary to apply an hourly rate to obtain the cost. This equation provides a convenient yardstick for comparing the efficiency of different skidding jobs, also aids an operator in effectively planning his work on jobs where road and landing costs are a factor.

Yarding.--On operations not readily accessible by truck, pulpwood was ordinarily bucked and stacked in the woods and hauled on sleds to truck landings during winter months. This study provided a rather limited sample of this phase, being confined to the work of 2 crews making a total of 30 trips. Observations included loads of one or $1\frac{1}{2}$ cords of spruce and fir yarded down hill for distances of 2,000 to 3,000 feet.

As indicated in figure 5, time required to load and unload sleds depends largely on stick size. Although the figure is based on average sticks, it probably indicates optimum size for handling. A pile of wood made up entirely of sticks 6.3 inch center diameter (110 per cord) probably could be handled most efficiently and in noticeably less time than indicated in the chart. Approximately 60 percent more time would be required to load and unload pulpwood where sticks average either 5.5 or 8.0 inches in diameter; in the first case because there are too many sticks to handle (150 per cord), and in the latter the sticks are too large to handle easily. Values read from the figure would be somewhat in error for any abnormal distribution in stick sizes. A cutting operation including a very high proportion of both large and small sticks might average 110

per cord, but would require far more handling time than would be the case with a restricted spread around the same average size.

Regardless of load size, round trip travel time including rest periods does not vary much from .019 minutes per foot of yarding distance. Assuming this travel rate, the following formula provides a basis for estimating yarding costs:

$$Y = \frac{C\ (L + U) + .019\ D}{C}$$

in which Y = Yarding time per cord in minutes C = Load in cords

D = Distance in feet

1/ L = Loading time per cord in minutes

1/ U = Unloading time per cord in minutes

If the same crew loads and unloads the sled, there is no need for segregating these two items in the above formula, however, the distinction facilitates an analysis of efficiency of different crew combinations. Is a driver working alone the most efficient unit? With a helper? With a part-time helper?

To demonstrate the utility of the formula, it is assumed that one cord loads averaging 120 sticks (6 inch center DIB) are yarded an average distance of 1,000 feet. Figure 5 indicates 34 minutes would be required to load, and 16 minutes to unload. In solving the equation, a team and driver would make the round trip in 69 minutes, and at 80 cents an hour, the cost per cord would be 92 cents. Assuming two men would load and unload in half the time required by the driver working alone, time per cord would be reduced to 44 minutes. Although a helper would not be gainfully employed while the team is travelling, his time would necessarily be charged against this operation, raising to $1.15 (35 cents per hour for helper) the crew and team cost per hour, but reducing the cost per cord to 84 cents. If two teams were yarding on the same area and a helper assisted in loading while the drivers unloaded without help, 52 minutes would be required for a round trip. In assigning half of the helper's wages against each unit, the cost per hour would be 97½ cents, or 84½ cents a cord. This analysis indicates that on short hauls where a relatively high proportion of the time is spent in loading and unloading, a helper will reduce the cost per cord approximately the same amount whether he works with one unit continuously, or assists two drivers in loading. Practical limitations may not show up in solving such theoretical problems, as a team may require more rest than would be obtained if two men loaded and unloaded scoots, also two men do not necessarily load and unload in half the time required by one man working alone.

1/ Man minutes per cord for given number sticks (figure 5).

Skidding versus yarding.--The skidding and yarding phases of this study were restricted to locations well adapted to each, but given certain basic facts, the skidding equation and yarding formula provide a means for determining distance beyond which yarding becomes more economical than skidding. As an illustration, let us assume a stand of trees with an average diameter of 8 inches will cut out 7.5 sticks per tree, 110 of which equal a cord of peeled pulpwood. (Figure 5). With a hauling distance of 350 feet and with skidding and yarding loads of .19 and 1.3 cords respectively, solutions for the equations follow:

Skidding time

$$\text{per cord} = \frac{.029\ (350) + 6.8\ (.19) + .89\ (2.8) - .65}{.19} = 70 \text{ minutes}$$

$$\text{Yarding time per cord} = \frac{1.3\ (47.5) + .019\ (350)}{1.3} = 52.6 \text{ minutes}$$

With these results, and presuming a man with one horse receives 60 cents per hour for skidding and a team with driver 80 cents for yarding, costs are identical; i.e., 70 cents per cord. Travel distance is an important factor in skidding, 100 feet making a difference in costs of 15 cents per cord. On the other hand, loading and unloading time are major considerations in yarding, but 100 feet difference in distance would alter costs per cord only 2 cents. Skidding appears cheaper up to 350 feet, and yarding more economical for greater distances, but this direct comparison between yarding and skidding costs does not properly indicate skidding limitations when all factors are considered. If trees are skidded full length, and bucked at the landing this job can be done more efficiently than in the woods, and piling costs too are lower.

Assuming wages for bucking and piling at 35 cents per hour, reference to figure 3 indicates that one man can buck 8-inch spruce for 94 cents per cord in the woods, 67 cents per cord at the landing. Assuming one cord piles in the woods and large piles without racks at the landing, there is an additional saving of 6 cents per cord at the landing. Although skidding and yarding costs are identical for 350 feet, this 33 cent differential resulting from economies in bucking and piling at the landing makes a skidding operation under these conditions more economical up to distances of 600 feet.

Trucking.--The trucking phase of this study included four different trucks on four jobs with hauling distances between 17 and 40 miles. Although individual trucks always carried approximately the same load, data obtained on 44 trips included loads ranging from 3 to 5 cords of peeled spruce and fir pulpwood. Although load size was a significant factor as it affected loading and unloading time, the limited amount of trucking data failed to show a correlation between load size and travel time. As it was impractical to count the number of sticks in each load, no data were obtained showing effect of stick size on time consumed in loading and unloading trucks. Had this information been obtained, the effect of stick size would undoubtedly have conformed to trends noted on the yarding operation.

The following regression equation, with a standard error of ± 36.8 minutes, is based on a driver with one assistant and is an expression of truck- rather than man-minutes.

$$T = \frac{6.29\ (D) + 19.36\ (C) + 37.9}{C}$$

in which T = Trucking time per cord in minutes

D = One way distance in miles

C = Load in Cords

For a given distance, time per cord varies inversely with load as all values remain fixed except C. Consequently, computed costs steadily decline with an increase in load size. Actually truck capacities are definitely limited, even though the data collected indicated that with prevailing good roads, the load had little effect on travel time. Lower maintenance costs for trucks hauling lighter loads somewhat offset this apparent advantage in overloading.

Partial versus clear-cutting.--Production time data were obtained on a 50-year old field spruce and fir stand where 47 percent of the original volume, or 22.5 cords per acre, was removed in making a heavy selection cutting. After cutting, the residual stand was made up largely of promising medium-sized spruce well distributed over the area. As opposed to this silvicultural selection system, a commercial clear-cutting on another part of the same stand included all trees that would yield 2 or more sticks of pulpwood and left a scattered residual stand of trees less than 5 inches D.B.H. This removal of 93 percent of the volume (40 cords) left a worthless stand of less than 3 cords per acre.

As the same crew cut the entire tract, comparable production time figures for the two methods of cutting were available. Table 3 indicates that the additional time required to fell, limb, and peel trees of the same size on the selection as compared with the clear-cutting operation, amounted to 28.8 percent for 4-inch trees, and decreased to 3.5 percent for 13-inch trees. In analyzing these differences, felling appeared to be the most important factor, while method of cutting had little or no effect on time required for limbing and peeling. Had this crew of choppers been accustomed to selective cutting they would undoubtedly have worked more efficiently and with little more hesitation than was the case in clear-cutting where trees were windrowed.

Even though production costs are higher in utilizing trees of a given size on a selection basis, average per cord costs may be lower in cutting selectively. The method of cutting handicap will be more than offset if the average tree removed is only one inch greater than would be the case in clear-cutting. However, on the job where both methods of

SECOND GROWTH SPRUCE AND FIR STANDS AFTER CUTTING 20 TO 25 CORDS OF PULPWOOD PER ACRE. IN 20 YEARS THE SAME AMOUNT CAN PROBABLY BE CUT FROM THE RESERVED TREES.

cutting were studied, trees removed were slightly below average size. This situation may be generally anticipated in making selection cuttings of this type in young, untreated second growth spruce and fir stands as the cut will be made up mostly of large crowned dominants, particularly fir, and small suppressed and intermediate spruce and fir. With reduced stumpage values, smaller size classes could not be handled economically and would properly remain in the woods under both methods of cutting. In this event average per cord costs would be lower for partial removal as the cut would be restricted mainly to larger size classes, while a commercial clear-cutting would include at least all trees that would pay their way.

Under this type of forest management, weaklings are largely eliminated in the initial cutting. Trees harvested in making second and subsequent selective cuttings on an area should be well above the stand average, because trees to come out in these later cuttings would be largely from the upper diameter classes.

The likelihood of windthrow following an opening up of the stand is a point frequently brought up in considering partial cuttings. On this particular area, the hurricane of September 21, 1938, took its toll, but losses were proportionately no greater than in adjacent undisturbed stands.

Aside from tree size, accessibility of a stand to a truck road and mill is the most important factor determining the margin between production costs and selling price. As the highest returns may be obtained from the most accessible tracts, an owner can afford to make and maintain substantial investments on such areas. Work in young stands is particularly restricted if the landowner is unwilling to make any investment to benefit his stand and will undertake only silvicultural improvement work that "pays its way", that is, products removed of sufficient value to at least meet the cost of making the thinning or improvement cutting. Intensive forestry should properly be on a sliding scale, starting at the road in young stands and gradually giving way in older and less accessible stands where only heavier cuttings will carry the cost of essential transportation improvements.

Relatively high stumpage values such as prevailed on the accessible farm woodlots included in this study make utilization of small suppressed trees and thinnings from young stands practicable and profitable. The fact that there is a margin for stumpage in utilizing practically all merchantable trees makes intensive forestry practices particularly attractive. However, such favorable economic conditions frequently necessitate a thorough program of education; otherwise, silvicultural considerations and land management aspects may be obscured. As maximum immediate returns per acre can frequently be obtained in utilizing all merchantable trees, many landowners and operators are tempted to follow a short-sighted policy of liquidation.

Favorable development of residual stands following relatively light partial cuttings in second growth spruce and fir were noted by Westveld 1/ and Snow 2/. Their investigations would indicate that over an extended period, maximum returns could ordinarily be obtained by making selective cuttings at intervals of from 5 to 10 years on areas where the owner maintains a considerable investment in growing stock.

Summary and Conclusions

1. Tree size, more than any other single factor determines cost of producing peeled pulpwood from second growth spruce and fir stands. Within the size range covered, trees from 4 to 13 inches in diameter breast high, maximum output is obtained for all phases of an operation in handling the larger if not the largest diameter class. Felling, limbing, peeling costs per cord increase rapidly below 8 inches, while bucking costs rise sharply below 6-inches in diameter. For both operations more than twice as much time is required per cord for 4- as compared with 13-inch trees. Although a consideration, tree size probably has less effect on skidding output than any other phase of the pulpwood operation. However, a load of small trees aggregating a relatively small cubic foot volume requires slightly more handling time than a load of large trees. Tree size is also an extremely important factor in yarding cost, because the tree size determines average stick size, and an increase of 1-inch in average stick size may reduce loading and unloading time sufficiently to offset an increase of half a mile in yarding distance. Although substantiating data were not obtained, the effect of stick size on time required to pile pulpwood and load and unload trucks would probably be much the same as shown for loading and unloading yarding sleds.

2. Crew size is an important factor affecting felling, limbing, peeling, and bucking output. One man can fell, limb, and peel about 30 percent more pulpwood alone than when working with a partner, while a 3-man crew is the least effective organization. In bucking, one man working alone is also more efficient than two men. Four men working at the landing with a power saw compared favorably with one man in bucking trees below 9 inches, but could not handle the larger sizes so economically.

1/ Westveld, Marinus. Silvicultural treatment of spruce stands in northeastern United States. Journ. of Forestry, Vol. 36, pp. 944-950, 1938.

2/ Snow, Albert G. Jr. Progress report on two sets of spruce thinning plots established in 1906 in Corbin Park, New Hampshire. Journ. of Forestry, Vol. 36, pp. 19-25, 1938.

3. Spruce is heavier and harder, more limby, and more difficult to fell than fir, and consequently requires more labor to produce a cord of pulpwood. Most of the additional time is required for limbing. No distinction was made between spruce and fir in obtaining piling, skidding, yarding, and trucking data. As these items are all primarily a matter of transportation, comparative data would undoubtedly have shown that the lighter fir could be handled and hauled more economically than spruce.

4. This study brought out the relative merits of different operating organizations on pulpwood jobs, ordinarily determined in large measure by accessibility to a truck road. Skidding should be restricted to relatively short distances, ordinarily less than 600 feet. Beyond this, yarding is more economical. However, a direct comparison between costs of skidding and yarding for a given distance is not sufficient. Economy of bucking and piling skidded trees at the landing rather than in the woods before yarding indirectly extends the practicable skidding distance. A helper for drivers of yarding sleds and trucks is good economy only on short hauls where much of the time is spent loading and unloading.

5. In selective cutting the time required for felling, limbing, and peeling trees of a given size is somewhat higher than in the usual commercial clear-cutting, with a spread of 28.8 percent in the 4-inch class, decreasing to 3.5 percent for the 13-inch class. This handicap is, however, more than offset if the diameter of the average tree in selective cutting is only an inch greater than would be obtained in clear-cutting.

Because heavy cuttings may be necessary on less accessible areas to insure sufficient volume to carry the cost of essential transportation improvements, lands accessible to truck roads and markets offer the best opportunity to practice intensive forestry. On such areas maximum annual returns over a long period will doubtless be realized by developing and maintaining a relatively large growing stock on the land through a series of light selection cuttings at intervals of from 5 to 10 years.

TABLE No.1.--Data on average trees based on measurements of second growth spruce and fir stands in Coos County, New Hampshire

D B H (inches)	Total height (feet)	Merchantable length (feet)	Merchantable top DIB (inches)	Sticks per tree	Merchantable cu.ft. volume per tree	Average: Stick volume	Average: Stick center DIB	Average: Number of sticks per cord 2/	Average: Number of trees per cord 2/
				Spruce 1/					
4	39.5	19.0	3.5	4.75	1.62	.341	3.9	281	59.1
5	40.5	22.0	3.6	5.50	2.30	.418	4.4	229	41.7
6	41.5	24.5	3.6	6.12	3.22	.526	4.9	182	29.8
7	43.0	27.0	3.7	6.75	4.58	.679	5.6	141	20.9
8	45.0	30.0	3.8	7.50	6.50	.867	6.3	110	14.7
9	47.0	33.0	3.9	8.25	8.86	1.074	7.0	89	10.8
10	49.5	36.0	4.0	9.00	11.30	1.256	7.6	76	8.5
11	52.0	38.5	4.1	9.82	13.90	1.415	8.1	68	6.9
12	54.5	41.0	4.2	10.25	16.95	1.654	8.7	58	5.7
13	57.0	43.0	4.3	10.75	20.82	1.937	9.4	49	4.6
14	59.5	45.0	4.4	11.25	25.60	2.276	10.2	42	3.7
				Fir 1/					
4	38.0	16.5	3.5	4.12	1.38	.335	3.9	286	69.4
5	39.5	20.0	3.6	5.00	2.04	.408	4.3	235	47.0
6	41.5	23.5	3.6	5.88	3.20	.544	5.0	176	29.9
7	44.5	27.0	3.7	6.75	4.77	.707	5.7	136	20.1
8	47.5	31.0	3.8	7.75	6.70	.865	6.3	111	14.3
9	50.5	34.5	3.8	8.62	8.90	1.032	6.9	93	10.8
10	53.0	37.5	3.9	9.38	11.28	1.202	7.4	80	8.5
11	55.5	40.0	4.0	10.00	14.30	1.430	8.1	67	6.7
12	57.5	42.5	4.2	10.62	17.52	1.650	8.7	58	5.5
13	59.5	44.5	4.4	11.12	21.10	1.897	9.3	51	4.5
14	61.5	46.5	4.5	11.62	25.00	2.151	9.9	45	3.8

1/ Based on 597 trees included in felling-limbing-peeling phase of study
2/ 95.8 cu.ft. per cord

TABLE No. 2.--Data on number of sticks of peeled spruce and fir contained in a standard cord of pulpwood

Average center d.i.b.	Solid Wood Volume	Number of sticks per cord 1/	Number of sticks per cord 2/
4	93.4	267	274
5	94.5	173	176
6	95.3	122	122
7	96.0	90	90
8	96.7	69	69
9	97.3	53	54
10	97.9	45	44
11	98.5	37	36
12	99.1	32	30
13	99.6	27	26

1/ Based on piles of stacked wood having different average D.B.H. values from curve to nearest stick.

2/ Assuming 95.8 cubic feet of solid wood per stocked cord (128 cu.ft.)

TABLE No.3.--Data on percent additional time required in felling, limbing, and peeling second growth spruce and fir in making heavy selection cuttings 1/ as compared with commercial clear-cuttings

D.B.H. (inches)	Additional time 2/ (percent)
4	28.8
5	14.4
6	10.8
7	9.3
8	8.0
9	6.8
10	5.7
11	4.6
12	3.9
13	3.5

1/ Based on 275 trees

2/ Curved value

Figure 1

PRODUCTION TIME FOR COMMERCIAL CLEAR-CUTTING BY TWO MEN FELLING, LIMBING AND PEELING SPRUCE AND FIR PULPWOOD FROM TREES OF DIFFERENT SIZES

Based on 597 Trees

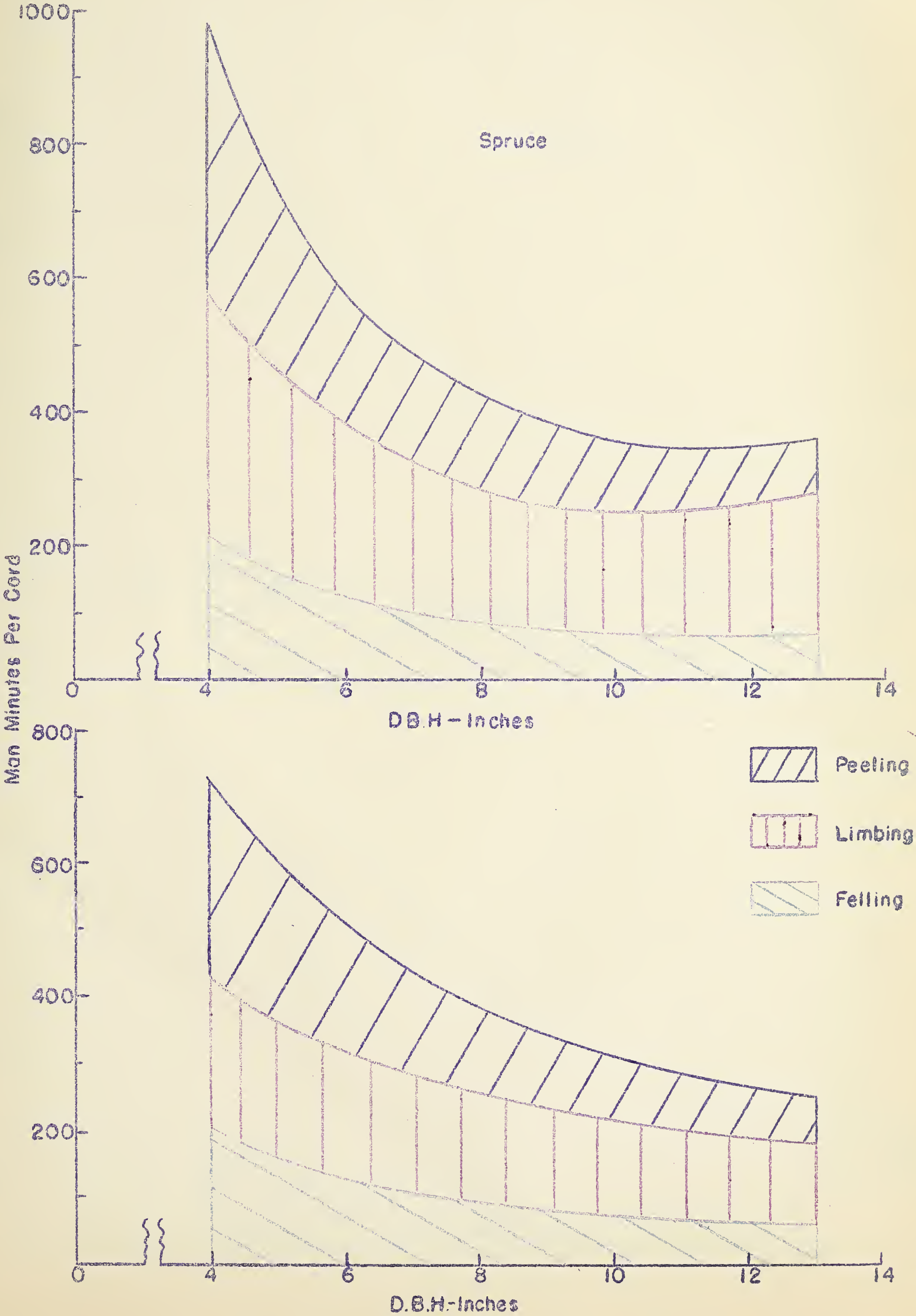


Figure 2

PRODUCTION TIME FOR DIFFERENT SIZE CREWS FELLING, LIMBING AND PEELING
SPRUCE AND FIR PULPWOOD

Based on 875 Trees

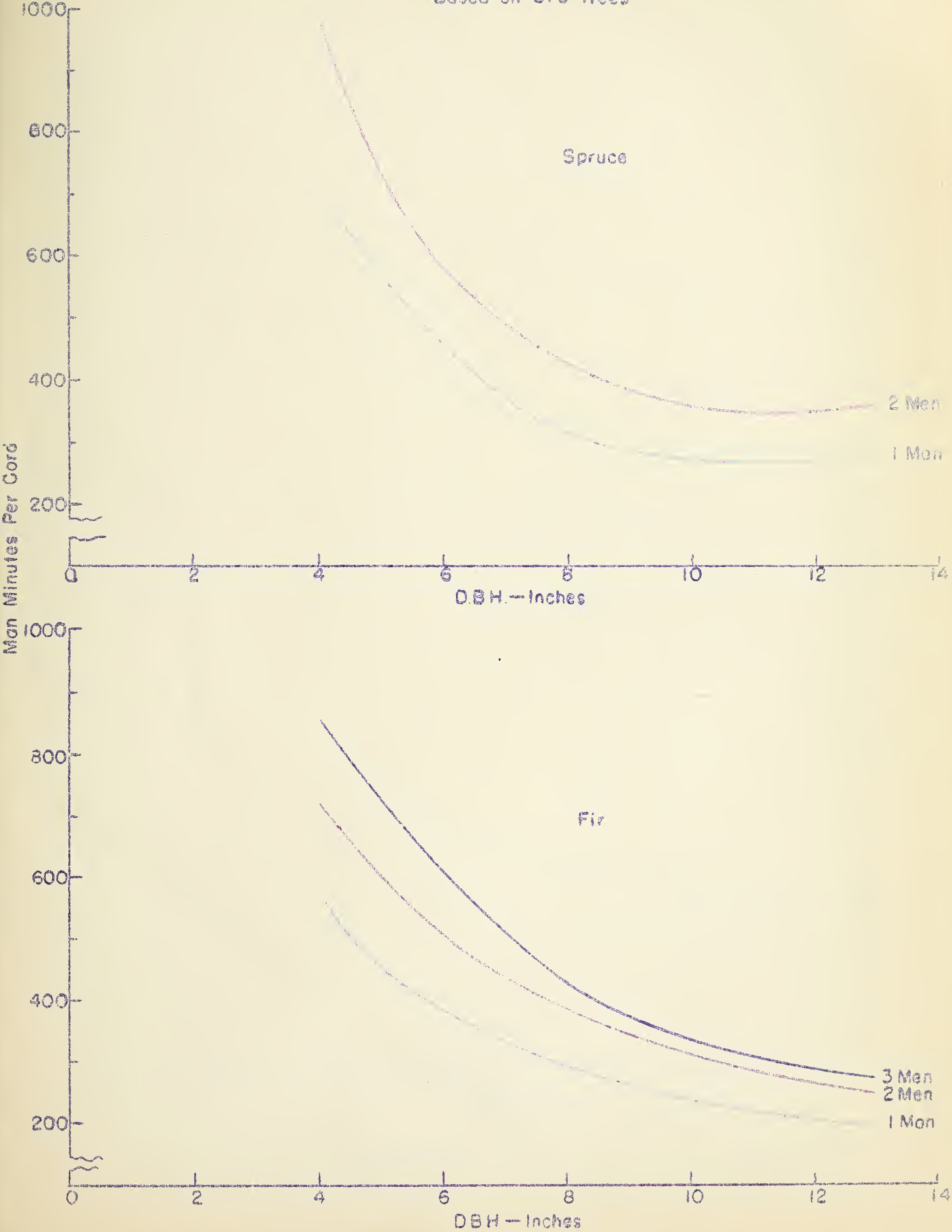
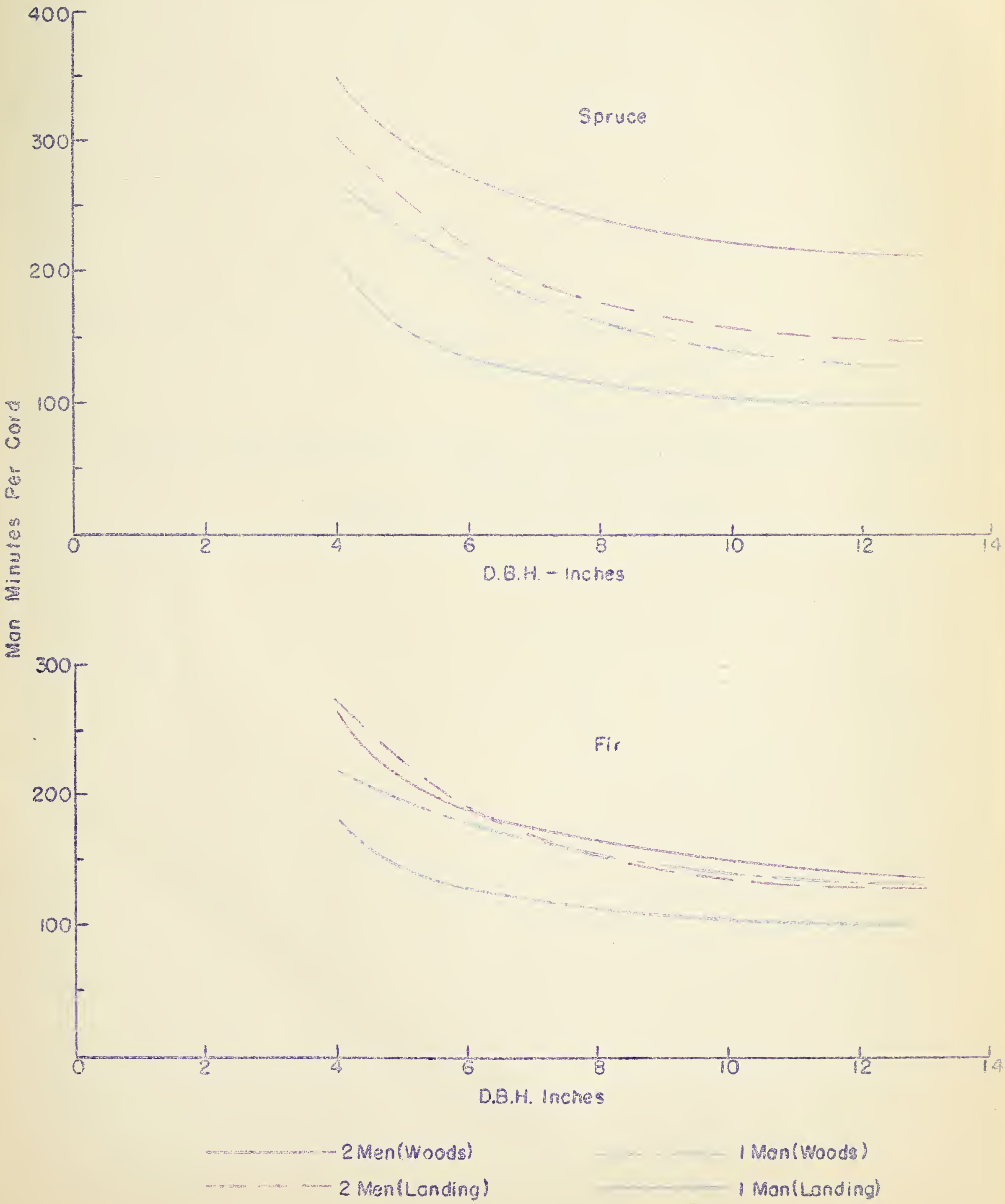


Figure 3

PRODUCTION TIME FOR ONE AND TWO MEN BUCKING DIFFERENT SIZE SPRUCE AND FIR IN THE WOODS AND AT THE LANDING

Based on 1388 Trees



PRODUCTION TIME FOR A 2 MAN CREW BUCKING DIFFERENT SIZE SPRUCE [illegible]
AT THE LANDING
Based on 293 Trees

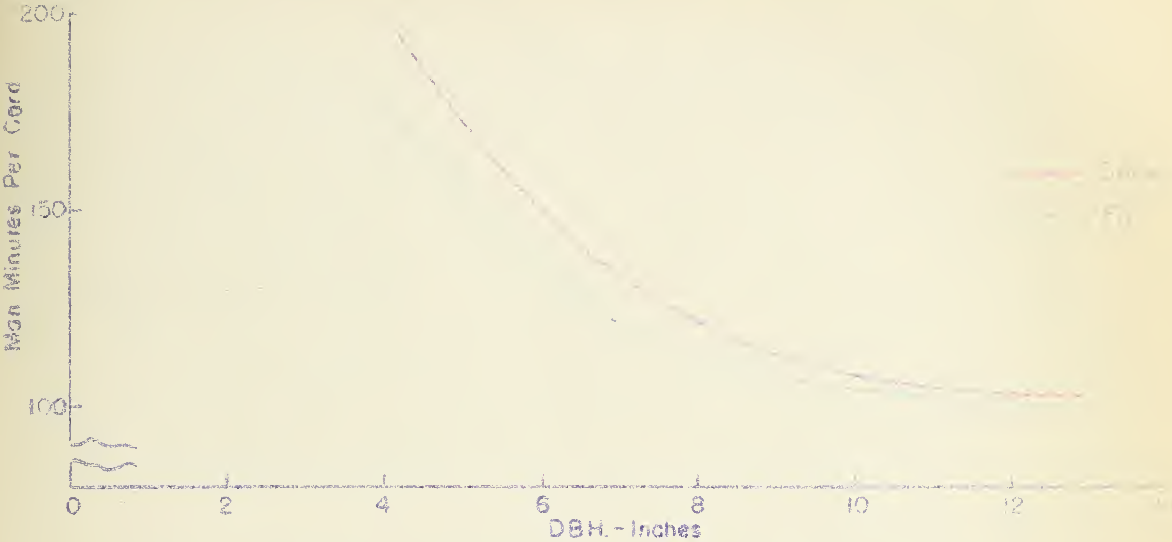
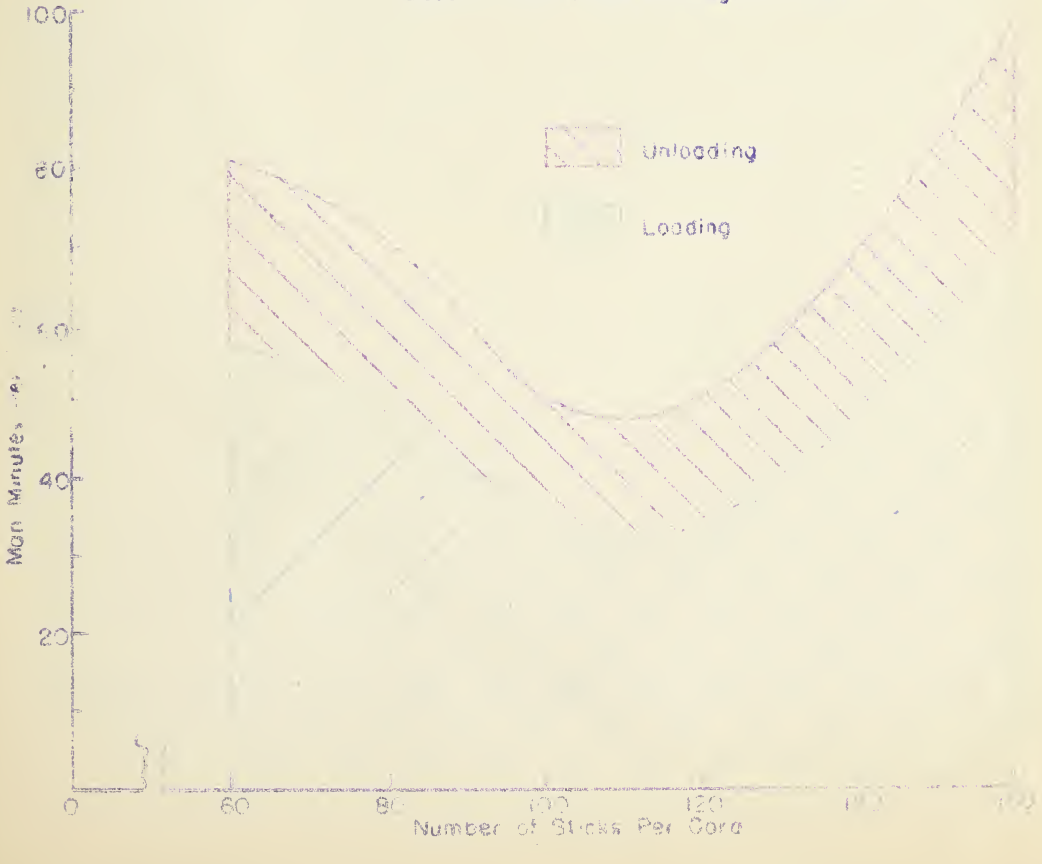


Figure 5

HANDLING TIME PER CORD IN LOADING AND UNLOADING SPRUCE AND FIR PULP[illegible]
OF DIFFERENT SIZES
Based on 30 Loads Totaling 36 Cords



Appendix

Practical application of production cost data

The utility of tables, figures, and equations developed on this study can readily be shown in analyzing typical pulpwood operations. In the absence of suitable concrete examples, two second growth stands are assumed, both site class 70, with 80 percent of full stocking.1/ In assuming ages of 44- and 56-years, the stands would contain 770 and 680 trees per acre respectively. For simplicity and to avoid duplicating computation work these stands are considered to be spruce, rather than typical spruce and fir mixtures. Table 4 indicates by size classes, a distribution of cut and reserve trees that might result from the application of good silvicultural practice. The table also indicates the result of typical commercial clear-cutting in these stands, with a third of the trees in the smallest size group (3" to 5") to be removed along with all trees above 5-inch D.B.H. The volume in cords (95.8 cu.ft. = 1 cord) to be obtained in clear or selectively cutting the two stands is also shown.

Table 5 provides a breakdown of production costs per cord and per acre in clear and selectively cutting of the two hypothetical stands. These costs were obtained by assuming the following wage rates: 35 cents per man hour to fell, limb, peel, buck, and pile, 60 cents for horse and driver in skidding, 80 cents for driver and team in yarding, and $1.40 for truck, driver, and helper. The hypothetical stands indirectly bring out the significance of accessibility in relation to transportation costs. The average distance from the 44-year stand to the truck road is assumed to be 400 feet, thence 20 miles to the mill, as compared with distances of 3,000 feet and 40 miles for the 56-year tract. Table 5 gives costs for each stand when operated as a yarding and also as a skidding chance; that is, with trees bucked in the woods and yarded in 4-foot lengths, and also skidded in tree lengths to a truck landing before bucking.

Felling, limbing, and peeling data are shown in table 5 for only the most efficient unit, one man working alone. Depending on tree size selective cutting costs were assumed to be 3.9 to 28.8 percent higher than clear-cutting the same trees. In spite of this differential, average costs per cord on both tracts were lower in selective cutting because the method of cutting handicap was more than offset by the increase in average tree size. A commercial clear-cutting of the 44-year stand cost $2.65 for felling, limbing, and peeling. This is 38 cents per cord more than for selection cutting on the same area. As output is largely determined by average tree size, costs were somewhat lower for the older stand, $1.96 per cord in making a partial cutting, and $2.09 if operated as a clear-cut chance.

1/ Meyer, Walter H. Yields of Second-Growth Spruce and Fir in the Northeast. U.S.D.A. Tech. Bull. 142, 1929.

In bucking, as in felling, limbing, and peeling the same relation exists between tree size and output. Bucking costs are lower when trees are bucked at a landing after skidding rather than in the woods before yarding. In some cases, as shown in table 5, place of bucking more than offset differences in average tree size. Largest average trees were obtained in selectively cutting the 56-year stand. Minimum bucking costs of 66 cents per cord were also obtained in this stand when trees were cut up at the landing, but when the same trees were handled as a yarding chance and worked up in the woods, bucking costs mounted to 92 cents. This is 10 cents per cord more than for the smaller trees on the 44-year area, clear-cut and handled as a skidding chance. All bucking costs in table 5 are based on the most efficient unit -- one man working alone.

Assuming wages of 35 cents per hour, piling cost 25 cents per cord either in the woods or at the landing. However, when handled as a yarding chance and bucked in the woods, there was an additional charge for building racks. As this item was uniform for each stack of wood (6 cents), cost per cord varied with pile size which in turn is indirectly determined by the volume removed per acre.

Skidding to a landing in tree lengths is economical for only relatively short distances even when taking into account the indirect economies in bucking and piling on a skidding chance. Table 5, skidding figures based on uniform loads of .15 cords, show prohibitive costs of $6 per cord for the 3,000 foot distance. Under the assumed conditions skidding and bucking at the landing would be more economical up to distances of about 500 feet, for greater distances it would be more efficient to yard pulpwood bucked at the stump. As compared with distance, size of tree is relatively unimportant, although trees selectively cut from the 56-year stand averaged 8.2 inches in diameter as compared with 6.6 inches in clear-cutting the same area. Skidding the smaller trees added only 5 cents per cord to the cost.

Number of sticks per cord is the primary consideration in a yarding operation. This factor largely determines time required to load and unload sleds, items that ordinarily account for more time than travel between woods and landing. The average bolt was 5-inch in diameter in clear-cutting the 44-year stand, and almost 6-inch in clear-cutting the older stand. However, this difference of less than an inch more than offset the 2,600 foot difference in yarding distance. Cost figures were based on uniform sled loads of 1.3 cords.

Trucking four cord loads 20 and 40 miles cost $1.30 and $1.99 per cord respectively. At least part of this 69 cent margin, in favor of the younger stand, would be wiped out were data available showing effect of stick size on time required to load and unload trucks.

Total production costs per cord as shown in table 5, reflect the importance of both tree size and accessibility. Production time declines with an increase in average tree size; consequently had both tracts been equally accessible minimum costs would be obtained in selectively cutting the older stand, while clear-cutting the 44-year stand would be most costly. However, accessibility of the younger stand to a truck road and mill more than offsets the size handicap since minimum costs of $5.49 per cord were obtained in selectively cutting the 44-year stand. Production costs based on this removal of only 3.85 cords per acre may be open to some question since this study did not include such light cuttings, and possibly the percentage factors (table 3) based on a removal of more than 20 cords are too conservative.

Net returns per acre for profit and stumpage on an acre may be greater for the larger volumes obtained in clear-cutting an entire stand in spite of higher costs per cord. This was true for both the 44- and 56-year stands unless the selling price was less than $7 per cord which is unreasonably low. Cashing in on everything that will meet the costs of production in order to obtain the maximum immediate returns precludes further income for at least 40 years, and usually involves destroying a thrifty growing stock that might under selective cutting continue to produce excellent growth dividends at frequent intervals.

TABLE No. 4.--Data on selection and clear-cutting of hypothetical 44-year and 56-year second growth spruce stands

Diameter group (inches)	Trees per acre: Original Stand	Trees per acre: Residual Stand	Trees per acre: Cut	Volume cut per acre (cords)
	44 Year Stand			
	Selection (18% Removal)			
3-5	453	453		
5-7	256	216	40	1.34
7-9	56	26	30	2.04
9-11	5	1	4	.47
Total	770	696	74	3.85
	Commercial clear-cutting (76% removal)			
3-5	453	302	151	2.55
5-7	256		256	8.61
7-9	56		56	3.80
9-11	5		5	.59
Total	770	302	468	15.55
	56 Year Stand			
	Selection (39% Removal)			
3-5	157	157		
5-7	285	235	50	1.68
7-9	178	90	88	5.97
9-11	50	16	34	4.01
11-13	10	2	8	1.42
Total	680	500	180	13.08
	Commercial clear-cutting (95% Removal)			
3-5	157	104	53	.89
5-7	285		285	9.58
7-9	178		178	12.08
9-11	50		50	5.90
11-13	10		10	1.77
Total	680	104	576	30.22

TABLE no. 5.--Summary of computed cost data of the hypothetical second growth spruce stands treated either as a skidding or yarding chance following clear or selective cutting

Operation	44-Year Stand (400 feet from truck road – 20 miles from mill)				56-Year Stand (3000 feet from truck road – 40 miles from mill)			
	Selection Av. D.B.H.6.6"		Clear-cutting Av. D.B.H. 5.9"		Selection Av. D.B.H. 8.2"		Clear-cutting Av. D.B.H. 6.6"	
	Per Cord	Per Acre	Per Cord	Per Acre	Per Cord	Per Acre	Per Cord	Per Acre
Yarding Chance								
Volume Removed (Cords)		3.85		15.55		13.08		30.22
Felling-Limbing-Peeling	$2.27	$8.74	$2.65	$41.21	$1.96	$25.64	$2.09	$63.16
Bucking (Woods)	1.01	3.89	1.17	18.19	0.92	12.03	1.00	30.22
Piling (Woods)	0.37	1.42	0.31	4.82	0.31	4.05	0.28	8.46
Yarding	0.86	3.31	1.41[1]	21.93[1]	1.24	16.22	1.34	40.49
Trucking	1.30	5.00	1.30	20.22	1.99	26.03	1.99	60.14
Total	$5.81	$22.36	$6.84	$106.37	$6.42	$83.97	$6.70	$202.47
Skidding Chance								
Volume Removed (Cords)		3.85		15.55		13.08		30.22
Felling-Limbing-Peeling	$2.27	$8.74	$2.65	$41.21	$1.96	$25.64	$2.09	$63.16
Bucking (Landing)	0.70	2.70	0.82	12.75	0.66	8.63	0.71	21.46
Piling (Landing)	0.25	0.96	0.25	3.89	0.25	3.27	0.25	7.56
Skidding	0.97	3.73	1.06	16.48	5.95	77.83	6.00	181.32
Trucking	1.30	5.00	1.30	20.22	1.99	26.03	1.99	60.14
Total	5.49	21.13	6.08	94.55	10.81	141.40	11.04	333.64

[1] Conservative estimate – Data not available on small average sticks.

TABLE No. 6 1/ — Production time for different size crews felling, limbing, and peeling spruce and fir pulpwood, based on 875 trees

D.B.H.	Man minutes per cord											
	1-man Crew				2-man Crew				3-man Crew			
(inches)	Felling	Limbing	Peeling	Total	Felling	Limbing	Peeling	Total	Felling	Limbing	Peeling	Total
						Spruce						
4	206	273	216	695	218	358	400	976				
5	158	233	178	569	162	302	280	744				
6	116	200	142	458	126	258	188	572				
7	84	175	110	369	103	226	158	487				
8	67	159	85	311	86	202	138	426				
9	59	150	74	283	77	183	122	382				
10	55	148	67	270	73	176	107	356				
11	53	152	63	268	70	180	95	345				
12	51	160	60	271	68	195	87	350				
13	49	172	58	279	67	210	83	360				
						Fir						
4	178	194	196	568	202	224	300	726	207	350	299	856
5	130	174	149	453	155	208	238	601	184	296	247	727
6	108	159	116	383	126	194	189	509	162	248	199	609
7	91	146	95	332	106	180	153	439	142	210	157	509
8	77	137	80	294	89	168	126	383	124	183	124	431
9	67	129	69	265	78	156	110	344	108	163	102	373
10	59	121	60	240	70	146	96	312	93	151	89	333
11	53	115	52	220	63	137	85	285	81	144	79	304
12	49	111	46	206	59	128	77	264	72	138	74	284
13	46	107	42	195	56	120	71	247	65	136	70	271

1/ Same as Figure 2 of text

TABLE No. 7.[1] Production time for one and two men bucking different size spruce and fir in the woods and at the landing - based on 1388 trees

D.B.H. (inches)	Man minutes per cord			
	One man		Two men	
	Landing	Woods	Landing	Woods
		Spruce		
4	209	265	299	348
5	153	233	258	296
6	135	204	221	272
7	124	179	191	255
8	115	161	173	240
9	108	150	164	230
10	104	142	158	223
11	102	136	154	218
12	100	132	149	214
13	100	128	146	212
		Fir		
4	182	220	276	265
5	144	199	222	213
6	129	180	193	189
7	120	165	172	175
8	113	154	155	166
9	109	146	143	159
10	107	140	136	152
11	105	136	133	147
12	103	133	131	142
13	101	131	130	138

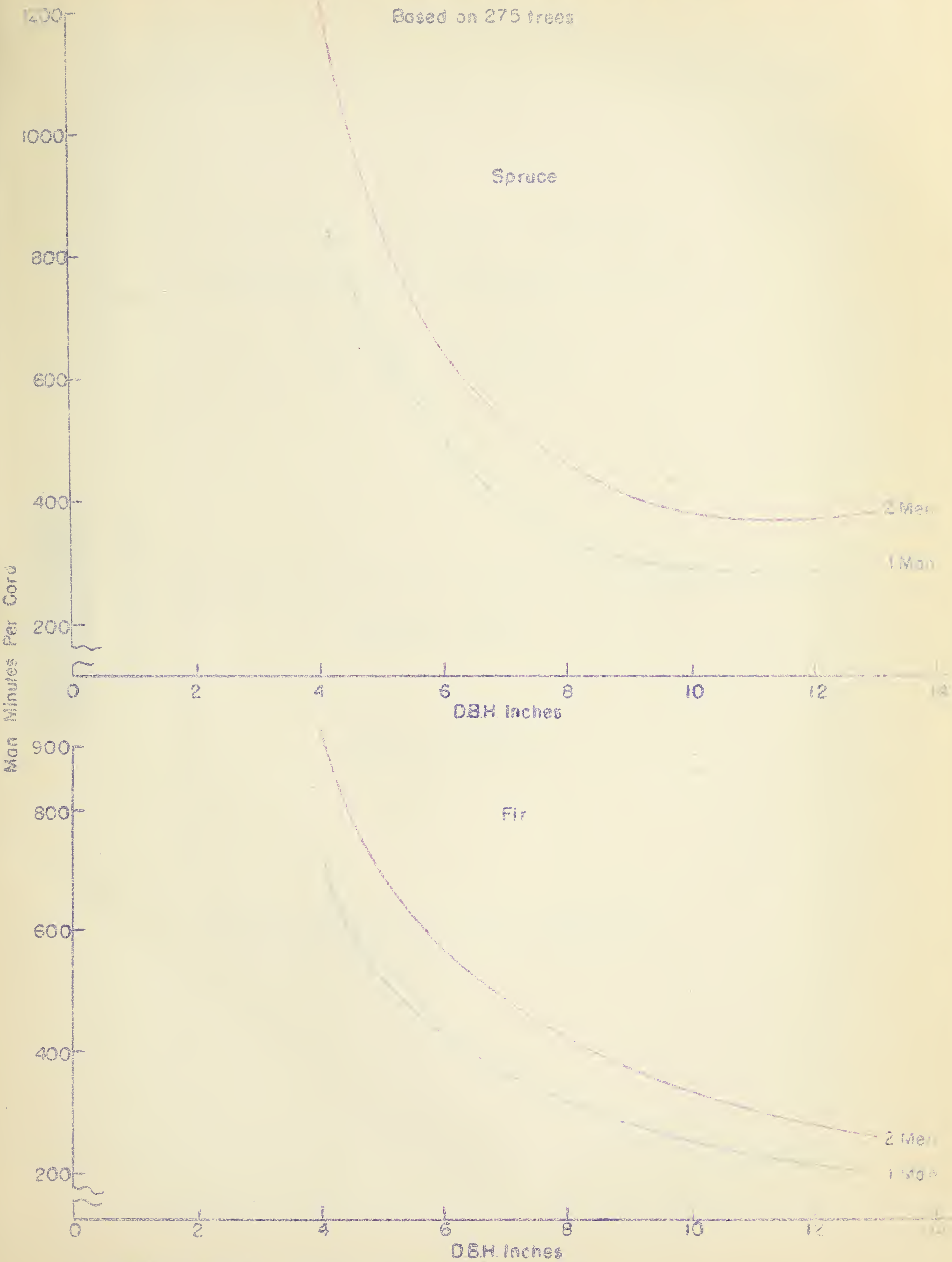
[1] Same as Figure 3 of text.

TABLE No. 8.[1]--Handling time per cord in loading and unloading spruce and fir pulpwood of different sizes -- based on 30 loads total - based on 30 loads totalling 36 cords

Number of sticks per cord	Average stick center d.i.b.	Loading time per cord (man minutes)	Unloading time per cord (man minutes)	Total time per cord (man minutes)
60	8.6	57.0	24.0	81.0
70	8.0	54.0	23.5	77.5
80	7.4	49.0	22.0	71.0
90	7.0	41.0	19.0	60.0
100	6.6	34.0	16.0	50.0
110	6.3	32.0	15.5	47.5
120	6.0	34.0	16.0	50.0
130	5.8	40.0	18.0	58.0
140	5.6	48.0	21.0	69.0
150	5.4	58.0	24.5	82.5
160	5.2	70.0	28.5	98.5

[1] Same as figure 5 of text.

PRODUCTION TIME FOR FELLING, LIMBING AND PEELING SPRUCE AND FIR TREES IN MAKING A HEAVY SELECTION CUTTING 1/



1/ Based on Table 3 — Factors applied to Fig 2 values